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DEVELOPMENT OF THE FARM MACHINERY INDUSTRY IN JAPAN: A CASE STUDY OF THE WALKING TYPE TRACTOR

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As is well known, technical change is one of the most important elements in agricultural development. However, it is also one of the most difficult process to undertake in less developed countries. Hence, if less developed countries can borrow advanced technology existing in developed countries, they may be able to achieve substantial gains in agricultural productivity. But, agricultural technology is location-specific, and the direct transfer of foreign advanced technology to less developed countries met with only limited success. In most cases, it is necessary to modify borrowed technology and generate an ecologically adapted and economically viable agricultural technology through adaptive research and development.[1]

In the process of technology transfer in agriculture from developed countries to less developed countries, it will be important to fulfill the following points through adaptive research and development.

① Agricultural technologies in developed countries are typically capital-using and labor-saving because of those countries' factor endowments. When these technologies are transferred to less developed countries with scarce capital and abundant labor, it is necessary to modify these technologies so that they are consistent with less developed countries' factor endowments.

② If the gap between the level of borrowed machinery technology and the level of farm machinery industry of less developed countries is too large, it will be necessary to simplify the machinery. If the imported machinery is too complicated, it will be laid aside once it is broken down since repair service is not usually available. Hence, it will be appropriate to simplify imported machinery so that it is in conformity with the technological level of farm machinery industry and the operational ability of farmers in less developed countries.

③ It is important that borrowed technology adapt well to agricultural production organization and the social and institutional framework of the rural society. Size and capacity of machinery should be in conformity with the scale of farm management. The cost of the machinery should be within the farmer's purchasing power.

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[1] Hayami, Yujiro and Vernon W. Ruttan, Agricultural Development: An International Perspective, (Baltimore: John Hopkins Press, 1971), pp. 169-190.

④ It is critically important to modify borrowed technologies through adaptive research so that they fit the ecological conditions of the less developed country. Since agriculture is a biological process, it is affected strongly by natural conditions unlike industrial production which is a non-biological process.

In order to consider the agricultural development of less developed countries by international technology transfer, it is important to make clear how developed countries have succeeded in the transfer of advanced technologies in agriculture through adaptive research and development. In this paper I will attempt to analyze the process of generating appropriate technologies through international transfer of technology in Japanese agriculture. As an example of generating appropriate technology in agriculture, the process of the development of the small-scale walking type tractor through international technology transfer will be analyzed.

I. *Development of the Walking Type Tractor in Japan*

The evolution of the walking type tractor occurred in three phases.[2] The first phase involved the actual transfer of technology from abroad. Garden tractors such as Bee Man, Utilitar and Simar were imported in the early 1920s and demonstration of cultivation was performed in some prefectures. The imported tractors turned out to be inappropriate for the natural, economic, and social conditions of Japanese agriculture. The import of garden tractors thus ended within a short period. The second phase saw the invention of a Japanese type tractor called the "power tiller." It incorporated some of the designs of imported garden tractors built before World War II. The power tiller was subject to several defects and was used only in limited areas. This led to the third phase in which walking type tractors were invented and widely diffused. These tractors signified the completion of an appropriate technology for Japanese agriculture. The defects of the power tillers were corrected and hand tractors and tailor type tractors were also developed with reference to imported garden tractors. The quality of these walking type tractors were good enough to replace draft animals completely. These walking type tractors were diffused at a high speed and reached their peak in 1974 when 3.4 million such tractors were in use in Japan. Export of the walking type tractors started increasing in the mid-1960s. In 1982 about 30 percent of the total production of walking type fractors was exported.

Developmept of the Power Tiller before World War II

As the Japanese economy began to boom after World War I, several factors led to an interest in farm mechanization. First of all, a large number of agricultural workers began migrating from rural areas to seek nonagricultural employment thus causing a labor shortage on the farms. Secondly, the wage rate for agricultural workers rose making farm mechanization more economically attractive. Finally, farmers' income rose because of the increased demand for agricultural products thereby increasing farmers' ability to purchase farm machinery. In response to these trends, the Japanese government and traders

[2] Hayami and Ruttan, ibid., pp. 181–182.

began importing garden tractors from Europe and the United States. Public demonstrations of land cultivation using garden tractors were performed in several prefectures.

Since the garden tractor was originally developed for the purpose of cultivating kitchen gardens and orchards, it encountered serious problems when used in Japan's paddy fields. The Ministry of Agriculture entrusted Tachikawa Agricultural Experiment Station in Tokyo to study the problem and compare eight kinds of imported garden tractors. The experiment station found that the imported garden tractors had a number of defects such as high prices, diseconomy due to the need of large amount of expendables, and complicated operating procedures.[3] In addition, as was pointed out earlier, imported garden tractors could not be readily used as land cultivating machines in paddy fields.

The following defects, for example, were pointed out with respect to Simar which, of the eight tractors, got relatively high scores.[4] First, when Simar was used in paddy fields, rice straw and grass coiled around the cultivating nail and made it difficult to move forward. When used in wet paddy fields, it cut through the soil but did not cultivate the land. Secondly, engine revolutions slowed down and stopped when pressure was increased since a high-speed engine with 1,200 revolutions per minute was used. Thirdly, it took two to three years for a farmer to get accustomed to operating the tractor because of the machine's complicated structure. When a Simar broke down, it was often laid aside because it could not be repaired due to lack of parts. Fourthly, the tractor cost about 1,900 yen making it a very expensive machine for farmers.

Several hundred garden tractors were introduced in prefectures such as Shizuoka, Aichi, Gifu, Ishikawa, Shiga, and Okayama. But, for reasons noted above, imported tractors were soon abandoned. Although direct application trials of foreign garden tractors in Japanese agriculture did not succeed, farmers' desire for tractorization remained strong. In their opinion, garden tractors should be remodeled so that they could be used effectively in paddy fields. As will be seen, this led to the development of a Japanese tractor in the southern part of Okayama Prefecture which was based, in part, on the designs of the foreign garden tractors.

(1) Inventor of the Power Tiller. The Swiss conducted public demonstrations of land cultivation by Simar tractors in Zaita village in Okayama Prefecture in 1921. The demonstration caused a sensation among farmers. Hiroshi Nishizaki, who watched this public demonstration, predicted that:

> Land cultivation by Simar will not go well since agricultural production methods and land conditions are different between Japan and foreign countries. Simar is equipped with a special engine and the price is very high. Tenant farmers will not be able to afford it. If it can be equipped with a water-cooled low-speed engine which farmers are accustomed to use in Okayama, farmers will be able to buy the body of the tractor at a lower cost and the cost of fuel will be cheaper too.[5]

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[3] Edayoshi, Hikozo, "Tokyo Fuka ni okeru Jido Kounki no Riyo (Utilization of the Power Tiller in Tokyo Fu)," Teikoku Nokai Ho, Vol. 30, No. 9; August, 1940.

[4] Kazuo, Wada, Kounki Tanjo (Birth of the Power Tiller), Fumin Kyoukai, 1979, pp. 116–117.

[5] Fukuda, Minoru and Hiromi Hosokawa, "Okayama Ken Nanbu ni okeru Nogyo Kikaika no Tenkai Katei (The Process of Development of Farm Mechanization in the Southern Part of Okayama Prefec-

Nishizaki soon started to develop a low-cost tractor which could cultivate paddy fields and be easily operated by farmers. Ichitaro Shiode, a tenant farmer cultivating 1.5 ha of land in Kojo village, collaborated with Nishizaki to develop a Japanese style tractor. Shiode had long wanted to mechanize the cultivation of wheat. When a power tiller was built on an experimental basis, Shiode conducted a trial cultivation on his field and, based on this trial, some of the machine's defects were corrected. By 1926 an experimental power tiller had been constructed. This power tiller had a water-cooled gasoline engine and a wood body. Power was transmitted from the engine to the cultivating edge by a chain. It was a cage rotary tractor with folk edges on the cage framework. Named the Marunishiki power tiller, two units were sold in 1927. The price of the body of the power tiller was 180 yen and the price of the engine was 300 yen. In total, the tractor cost 480 yen or about one-fourth the price of the Simar. Nishizaki obtained a patent for the power tiller in 1928.

Hatsugoro Itano was another inventor of the power tiller. Inspired by Yosaburo Hirabayashi, a farmer in Fujita village, he started research on a Japanese style tractor in cooperation with Hirabayashi in 1923. An experimental power tiller was completed in 1926 and sold to farmers around Kojo village under the name of Itanoshiki Rikuougo.[5] Itanoshiki Rikuougo had a number of advantages over the Marunishiki power tiller because it could more easily cultivate the clay soil of Kojo village.

The power tillers invented by Nishizaki and Itano in the mid-1920s were soon followed by other models one right after the other. Yasuhiro Fujii, for example, started production and sales of the Fujiishiki power tiller in 1932. By 1938 there were at least 22 power tiller producers in Japan.

Three types of power tillers were produced by the middle of the 1930s: rotary type, crank type and screw type. The rotary type power tillers cultivated land by using a horizontal axis around which about ten cultivating edges were attached. The rotary type power tillers were produced mainly in Okayama Prefecture.

Crank type power tillers cultivated land by moving the cultivating edge up and down much like a farmer using a hoe. This type of tractor was unique to Japan. Akira Saito, who was producing break barrows and cultivators for draft animals in Tokyo, first produced crank type power tillers under the name of Yamasa in 1935. Syojiro Saito, who was producing power threshers in Okayama City, produced and sold crank type power tillers under the name of Spee. Yokichi Hirose, who was producing power threshers in Ishikawa Prefecture, also produced crank type power tillers under the name of Hirose S in 1936.

Screw type power tillers cultivated land by using several vertical screw-shaped axes. Heijiro Furukawa, who was producing paddy field break barrows in Ishikawa Prefecture, started production and sales of screw type power tillers in 1938. The Kotani Farm Implement factory also produced and sold screw type power tillers.

(2) Improvement of the Power Tiller. It was the farmers in Kojo village in Kojima County of Okayama Prefecture who first bought the power tiller. When the power tiller

ture)," Nogyo Hattatsushi Chosakai Hen, Nihon Nogyo Hattatsu Shi (History of the Development of Japanese Agriculture), Betsukan Ge, Chuou Koron Shya, 1959, p. 193.

[6] Fukuda and Hosokawa, ibid., p. 195.

TABLE 1. IMPROVEMENT OF ITANOSHIKI POWER TILLER

Date of experiment	Horsepower	Average depth of cultivation	Average cultivation hours per 0.1 ha
May 1935	3 h.p.	8.0 cm	2 hours 20 minutes
Nov. 1938	3 h.p.	12.0 cm	1 hour 27 minutes
April 1941	4 h.p.	10.9 cm	1 hour 10 minutes

Source: Yoshioka, K. (1941), p. 12, Table 3.

was initially used to cultivate the clay soil of Kojo village, however, there were many troubles. The most serious were the slowness of cultivation and the shallowness of cultivation (e.g. cultivation depth was only about 3 cm). As a result, the power tiller was used mainly for preparing rice seed beds.

The cultivation capacity of power tillers gradually improved as these defects were corrected. Table 1 shows the change in cultivation capacity of the Itanoshiki Rikuougo tractor as an example of such improvement. The time it took to cultivate 0.1 ha of land decreased by one half and depth of cultivation increased considerably over a six-year period. The uses of the power tiller also gradually increased. It started being used, for example, for cultivation of wheat and to prepare fields for the planting of rush or, in the case of paddy fields, rice.[7]

The inventors and producers of the power tiller were small-scale farm machinery and implement producers. Their technology was simpler than that of the imported garden tractors. They produced only the body of the power tiller and not the engine. The structure of the power tiller was designed so that it could be used with a ready-made, water-cooled petroleum engine. This limited the capacity of the power tiller but reduced its costs so that farmers could afford to purchase the technology.

Development of the Walking Type Tractor after World War II[8]

Immediately after World War II, the machinery industry was confronted with excess capacity in terms of its production facilities and manpower due to the disappearance of the military demand. Many converted munitions factories entered into farm tractor production. Big modern companies that were technically more sophisticated such as Kubota, Ishikawajima Shibaura, and Shin Mitsubishi Juko started research and development on a walking type tractor. Iseki and Sato Zouki which were specializing in the production of farm machinery and implements also started to produce a walking type tractor around 1947–48.

The research and development of walking type tractors arose for three reasons. First, the power tiller was heavy (e.g., about 350 kg) because it was equipped with a heavy engine. This meant that the operation of the power tiller in the paddy field was extremely difficult. In order to correct this situation the companies tried to develop lighter engines, Secondly,

[7] Yoshioka, Kinichi, Koun Seichi Gijutsu no Tenkai (Development of the Technology of Soil Preparation), Teikoku Nokai Ho, Vol. 31, No. 8.

[8] This section relies on Sengo Nougyou Gijutsu Hattatsu Shi (History of the Development of Agricultural Technology after World War II), Vol. 1, (Norin Tokei Kyoukai, 1970), pp. 1029–1041, Shin Norin Shya, Nokisangyou Hyakunen (One Hundred Years of Farm Machinery Industry), 1968.

the power tiller had been designed exclusively for cultivating land and thus could not be used for other farm operations. Owners of the power tiller, for example, still had to use draft animals to till a rice field or to transport crops. Since this was uneconomical for power tiller owners, efforts were made to develop a multi-purpose tractor. Thirdly, the price of the power tiller was too expensive for small scale farmers. Research and development activities were thus carried out to produce a cheaper tractor.

The efforts of the big modern companies led to improvements in the power tiller as well as to the development of new types of tractors modeled after the old imported garden tractors. These included:

(1) Improvements of the power tiller. The power tiller was equipped with a water-cooled, low-speed engine with an engine weight of about 45 kg per horsepower. Because of the heavy weight of the engine, the horsepower of the power tiller was limited to 2 to 4 h.p., Kubota Tekkojo invented a water-cooled, middle-speed engine of 5 to 6 h.p. and 6–8 h.p. in 1950. The weight of this engine was about two-thirds that of the low-speed engine. This engine was also superior with respect to fuel consumption rate, durability and ease of handling. Due to the increase in horsepower, land cultivation efficiency was improved and the depth of cultivation was increased.

The power tiller of the pre-war period was not equipped with any water-proof device and thus could not be used to till rice fields. An oil seal made of synthetic rubber was first designed for the power tiller around 1952. An improved version with a lip arranged in a three-fold manner was introduced in 1955. This allowed the power tiller to be used to till rice fields without soil and mud water affecting the cultivating axes.

Several kinds of cultivation nails were also invented to increase the efficiency of cultivation. A hatchet nail (nata zume) was introduced in 1952. When land was cultivated with this nail, fewer rice straws and weeds coiled around the cultivation axes. Tomoe and other nails were also invented to cultivate land efficiently given particular land conditions.

The power tiller of the pre-war period was equipped with steel wheels and had to be carried to the field by a cycle trailor. With the introduction of an air tube rubber tire, the power tiller could not only be driven to a field but could be used to carry baggage. In summary, these improvements permitted increased cultivation efficiency, widened the range of use, and allowed for a cultivation depth that was comparable to that achieved by plowing with a horse.

(2) Hand tractor. A hand tractor was also developed in response to some of the problems with the power tiller. These tractors were lighter and had a wider use. Big manufacturing companies such as Mitsubishi Jukogyo and Ishikawajima Shibaurakikai started research and development on hand tractors by borrowing designs from abroad. The hand tractor was first made public in 1947.

The hand tractor was a pull type garden tractor with attachments. It was equipped with an air-cooled, high-speed engine. Its total weight was 200–250 kg which made it lighter than the power tiller. Hand tractors were designed with many kinds of interchangeable attachments in order to increase the rate of utilization. The hand tractor was used not only in paddy fields but also in upland fields. In 1950, there were three types of hand tractors: Mitsubishi, Shibaura and Komehara. The tractors were mainly diffused in upland field areas of such prefectures as Aomori, Nagano, Fukushima, and Hokkaido.

(3) Tailor Tractor. A garden tractor named Merry Tailor was imported from the

United States by Hakoneya in 1952. Saioushya started production and sales of Merry Tailor in cooperation with Japan Merry Tailor in 1953. Merry Tailor was equipped with a 2 to 3 h.p. air-cooled, high-speed engine and the structure was extremely simple. It had a wide use because of its interchangeable attachments. The price was about 100 thousand yen or one-half the price of the power tiller.

The major defects of Merry Tailor when used in a paddy field were its insufficient land cultivation depth and complicated operating procedures. Adaptive research and development was soon undertaken to address these problems and adapt the machine to Japanese agriculture. Merry Tailor was modified, for example, so that it could be attached to a Japanese plow. Engine horsepower was increased in order to improve cultivation efficiency. A side clutch was also built into the machine to make direction changes easier. This allowed for three speeds when going forward: low, medium and high. It also made it possible to go in reverse. By attaching rubber tires, the Merry Tailor could also be used as a cart. In this way the Japanese tailor tractor was created.

The power tiller was mainly used in flat areas and was not used in fields on an incline or on terraced fields. On the other hand, the tailor tractor was rapidly diffused among upland fields and orchards. The tailor tractor was also used often to pull trailors. In some areas about 60 to 80 percent of the total operation hours involved transportation.

The major thrust of adaptive research and development was to adapt tractor technology to land ownership conditions in Japan. In 1960, for example, the average size of farms was about 1.0 ha and land holdings were often scattered. For this reason, tractors were sought which could be used on small plots and for a number of purposes, With the development of the small-scale, multi-purpose, walking type tractors described above, the substitution of draft animals and manual laborers by tractors progressed rapidly.

II. *Development of the Farm Machinery and Implements Industry*

It was after World War I that the modern industrial sector arose in Japan. It was also during this period that farm machinery began to be used in agricultural production and, hence, that a farm machinery industry started. Table 2 shows the number of new farm machinery and implements enterprises with more than five workers that were created from 1868 to 1936. According to this table, the number of new enterprises increased sharply after World War I. At the end of 1936, for example, there were 367 factories with more than five workers in the farm machinery and implements industry and about 71 percent of them were begun after World War I. Although the number of enterprises in the farm machinery and implements industry increased after World War I, the scale of enterprise was still very small. According to the 1939 census (which was the first census to document the scale of enterprises), there were 13,886 factories in the farm machinery an implements industry. This implies that there was on average one factory in each town and village. Of these, 13,276 factories or 95.6 percent had less than five workers. These small factories, were responsible for 38.9 percent of the total production of the farm machinery and implements industry.

Table 3 shows changes in the scale of production in the farm machinery and implements industry from 1929 to 1941. As can be seen, the scale of production has been gradually

TABLE 2. NUMBER OF NEW FACTORIES IN THE FARM MACHINERY AND IMPLEMENTS INDUSTRY

Year	Number of new factories	Number of new factories per year
1868–83	6	0.4
1884–88	3	0.6
1889–93	7	1.4
1894–98	3	0.6
1899–03	14	2.8
1904–08	22	4.4
1909–13	33	6.6
1914–18	55	11.0
1919–23	66	13.2
1924–28	62	12.4
1929–33	42	8.4
1934–36	39	13.0

Source: Ministry of commerce and Industry, Statistical Tables for Factories.

TABLE 3. NUMBER OF FACTORIES IN THE FARM MACHINERY AND IMPLEMENTS INDUSTRY CLASSIFIED BY THE NUMBER OF WORKERS

Number of workers	Year												
	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941
5– 10	146	166	172	177	226	219	208	239	323	328	365	388	402
10– 15	23	14	19	23	30	29	33	44	51	55	89	112	136
15– 30	16	14	10	8	14	27	38	43	55	64	82	105	131
30– 50	12	9	8	14	13	12	13	20	18	25	36	35	49
50–100	5	5	1	4	8	16	11	13	18	22	23	28	28
100–200	1	—	1	3	2	1	6	7	6	6	15	13	17
200–500	—	—	—	—	—	1	1	1	1	1	—	1	4
Total	203	208	211	229	293	305	310	367	473	501	610	682	767
Index (1929=100)	100	102	104	113	144	150	153	181	233	247	300	336	378

Source: Same as Table 2.

increasing. The number of factories with five to ten workers as a proportion of all factories with more than five workers, for example, was 72 percent in 1929 and dropped to 52.4 percent by 1941. Statistical information on factories with fewer than five workers was not available.

Table 4 shows the total amount of production of the farm machinery and implements industry from 1929 to 1941. Production of farm machinery and implements, we see, remained fairly constant from 1929 to 1934 and then increased at a high rate during the period 1935–40. Because of the conversion of factories from war to peace-time purposes, the number of farm machinery and implements factories increased after World War II. The number of factories with more than five workers, moreover, increased 1.67 times within two years from 1,009 in 1945 to 1,683 in 1947. Production of farm machinery and implements also increased sharply during this time as noted earlier.

The Japanese economy, however, entered into a recession in 1949. Under Doge Line policy, the farm household economy was depressed because of increases in taxes and com-

TABLE 4. AMOUNT OF PRODUCTION OF THE FARM MACHINERY AND IMPLEMENTS INDUSTRY

Unit: Yen

Year	Farm machinery	Farm implements	Total
1929	4,418,756	4,181,265	8,600,021
1930	3,589,150	3,016,369	6,605,519
1931	2,914,996	2,459,796	5,374,792
1932	4,297,720	3,187,430	7,485,150
1933	4,756,029	5,023,786	9,779,815
1934	5,720,304	5,178,672	10,898,976
1935	8,599,530	5,824,586	14,414,116
1936	11,021,222	5,171,958	16,193,180
1937	14,157,224	8,448,974	22,606,198
1938	19,584,886	8,678,116	28,263,002
1939	23,434,050	10,437,844	33,871,894
1940	32,172,843	15,202,029	47,374,872
1941	33,389,333	20,745,732	54,135,065

Source: Same as Table 2.

modity prices, on the one hand, and suppression of rice prices on the other. According to the Farm Household Economic Survey, the average farm was operating at a deficit in 1949. As a result, the demand for farm machinery and implements decreased. Faced with large inventories of farm equipment, many factories tried to convert to other uses and the farm machinery and implements industry as a whole was thrown into crisis. The Korean War in 1950, however, led to a revival of the Japanese economy and facilitated the process of conversion. By 1951 many former farm machinery and implements factories had been converted for other production purposes.

According to the 1953 census, the number of factories in the farm machinery and implements industry was 3,708, a drastic decrease from the 13,886 factories which had existed in 1939. The proportion of factories with less than three workers was 71.3 percent in 1953. According to the Statistical Tables for Factories, the number of factories with more than five workers was 1,067 in 1953 or about the same number as in 1945.

The introduction of a national testing system for farm machinery and implements in 1949 led to a wave of modernization in the industry. The number of factories employing conveyer systems for assembly purposes and/or limited gauge systems, for example, increased. At the same time, the national testing system led to the demise of many factories which had been producing inferior products. The share of production of medium and large-scale factories started increasing as a result of these modernization processes. Factories with more than 300 workers, for example, accounted for more than 30 percent of the total production of the farm machinery and implements industry in 1954. The concentration of production in large-scale enterprises and use of mass production techniques gradually became the accepted practices in the farm machinery and implements industry.

Development of the Walking Type Tractor Industry

The power tiller was produced mainly in the southern part of Okayama Prefecture in the early stage of its development. As the power tiller diffused, production of the power

TABLE 5. PRODUCTION CAPACITY, PRODUCTION NUMBER, PRICE, AND LOCATION

Name of power tiller	Production capacity per year (unit)	Production number in 1938 (unit)	Price (yen)	Location
Koshibashiki power tiller	—	7	150	Okayama
Itanoshiki Spiidogo small-scale power tiller	100	80	240	〃
Itanoshiki Rikuougo small-scale power tiller	250	173	300	〃
Itanoshiki power tiller	150	—	300	〃
Marunishiki power tiller	100	215	210	〃
Okayamago tractor	30	—	220	〃
K. O tractor	—	50	230	〃
Fujiishiki Jobugo power tiller	200	500	280	〃
Nitsuto tractor	200	200	250	〃
Suehirogo tractor	—	17	260	〃
Toroku power tiller	200	—	300	〃
Komeya power tiller	300	117	240	〃
Spii power tiller	—	100	290	〃
Yabukishiki power tiller	—	250	490	〃
Mizuhatashiki power tiller	—	—	—	〃
Minematsushiki power tiller	—	—	—	〃
Center power tiller	100	—	360	Shizuoka
Hiroseshiki power tiller	200	—	490	Ishikawa
Hiroseshiki B-gata power tiller	200	—	490	Ishikawa
Omaeshiki power tiller	—	—	191	Shiga
Nichino crank power tiller	—	—	410	Osaka
Chuoshiki power tiller and Break barrow	—	—	—	Osaka

Source: Yoshioka, K., Basic Problems of Farm Mechanization, 1941, pp. 298–9.

tiller started in other prefectures too. The rotary type power tiller, for example, was produced in Okayama and Shizuoka Prefectures. The crank type power tiller was produced in the wet paddy field areas and the semi-wet paddy field areas of the Ishikawa, Shiga and Osaka Prefectures. The screw type power tiller was produced in Toyama Prefecture. Table 5 shows the location, production capacity, production number and sales price of the power tiller in 1938. The total number of power tiller producers was 22 and was broke down as follows: 16 in Okayama Prefecture; 2 each in Osaka and Ishikawa Prefectures; and 1 each in Shizuoka and Shiga Prefectures. Production capacity of the power tiller producer was generally small (e.g., several hundred units per year). Fujii Shoten produced the largest number of power tillers per year (e.g., 500 units in 1938) while the other producers manufactured fewer machines and were far from utilizing mass production methods. Beginning in 1937, however, the total number of units produced by each factory began to increase.

After World War II the number of enterprises producing the walking type tractor, as previously discussed, increased due to the conversion of factories for this purpose. Kubota Tekkojyo started production and sales of the walking type tractor in 1947. Mitsubishi Jukougyo began production of the hand tractor in 1948. Saiosya started production and sales of Merry Tailor in 1953. Soon, many enterprises (e.g., 152) started to produce tailor tractors. In 1955, Honda Giken began to sell walking type tractors at a price that

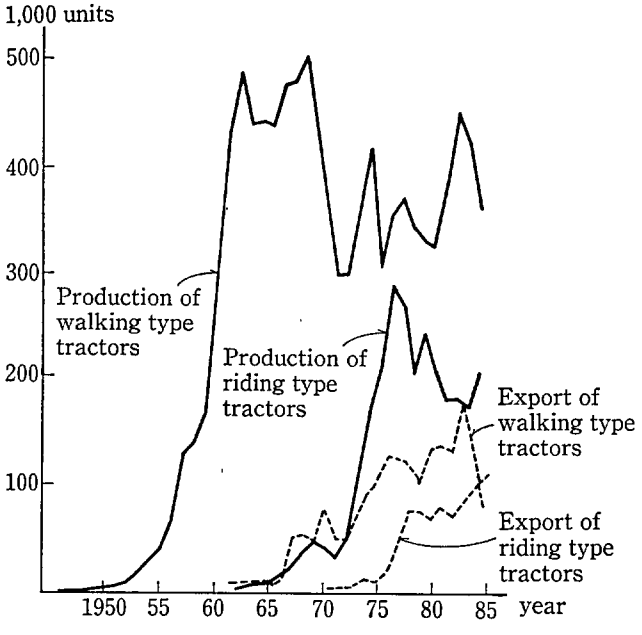
was 20 percent lower than the average price of that time. Competition became so fierce that the number of enterprises going bankrupt began to increase during this period.

Iseki founded the Iseki Farm Machinery Sales company in 1954 and proceeded to systematize sales. Kubota and Mitsubishi also began systematization of product sales at this time.[9] Monopolization of the tractor industry began around 1953 with five large companies—Kubota, Yanmar, Mitsubishi, Iseki and Sato—controlling large portions of the tractor market. The number of enterprises producing the walking type tractor, for example, had fallen to just a little more than 10 by 1965.

Production Trends in the Walking Type Tractor

Ten units of walking type tractors were produced in 1931 as compared to 2,581 in 1940 when production was at its pre-war peak. When the Pacific War broke out, materials became scarce and so the number of walking type tractors produced fell to 60 by 1945. Production gradually recovered after the war and exceeded the pre-war peak period by 1950 as shown in Figure 1. Production continued to increase at a high rate after 1950. The annual average growth rate was 41.6 percent, for example, during the period 1950–62. After 1962, production decreased a little but it increased again and reached its maximum of 500,000 in 1968. The production of walking type tractors showed a cyclical movement throughout the 1970s and 1980s. As the production and diffusion of the riding type tractor increased,

FIG. 1. PRODUCTION AND EXPORT NUMBER OF TRACTOR



Source: Nogyo Kikai Nenkan (Farm Machinery Yearbook), (Shinnorinsha, 1987).

[9] Shin Norin Shya, ibid., p. 130.

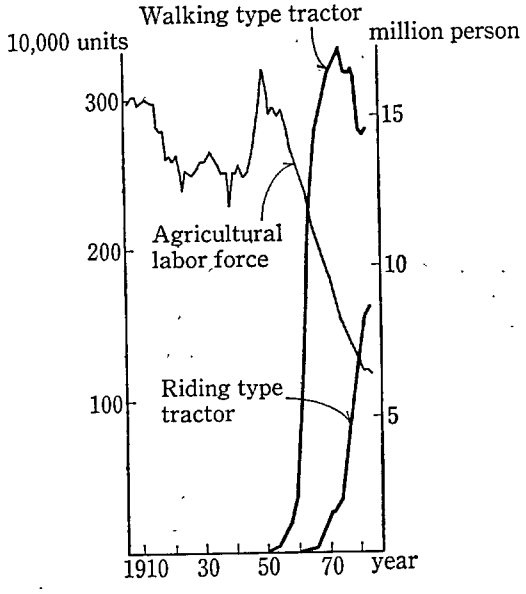
for example, substitution of the walking type tractor by the riding type tractor took place. The walking type tractor with more than 5 horsepower, in particular, was replaced to some extent by the riding type tractors. Production of small-scale walking type tractors of less than 5 horsepower, however, continued to increase in the 1970s and reached its peak in 1982.

Diffusion of the Walking Type Tractor

The number of walking type tractors diffused in 1931 was 98. As the efficiency of the tractor improved and the price of the power tiller decreased relative to the wage rate, the number increased gradually and reached 7,436 in 1942. The number of power tillers diffused in 1946 immediately after World War II was almost at the same level as those diffused in 1942. Production and diffusion of the walking type tractor steadily increased until the first half of the 1950s as shown in Figure 2. The number of walking type tractors diffused was 513,749 in 1960 and rose to 2,725,430 by 1965. The peak was reached in 1974 with 3,374,910 walking type tractors diffused. In the mid-1970s the number of walking type tractors being diffused began to decrease, in part, because of the introduction of riding type tractors as previously noted.

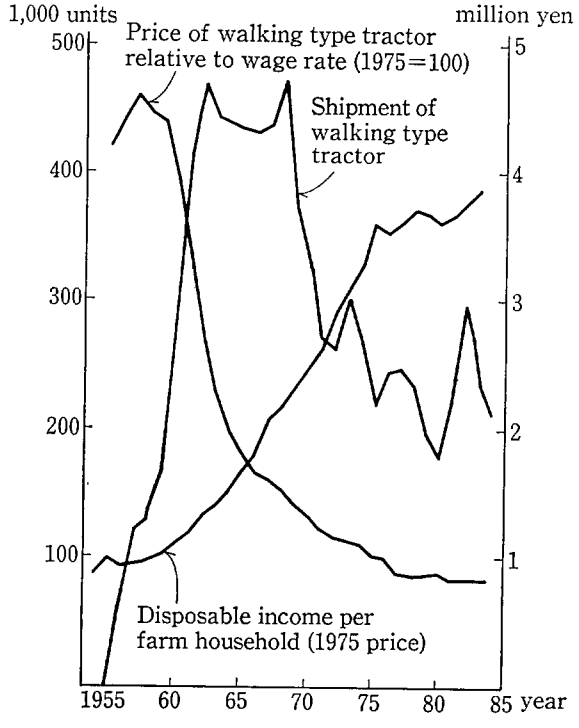
The growth in tractorization may be explained at least in part by the creation of an appropriate technology by the middle of the 1950s, namely: the invention of small-scale

FIG. 2. NUMBER OF TRACTOR AND AGRICULTURAL LABOR FORCE



Sources: Number of tractors: same as Figure 1. Number of agricultural labor force: for 1910–1960, Choki Keizai Tokei: Noringyo (Long-term Economic Statistics of Japan: Agriculture and forestry), (Toyo Keizai Shinposya, 1966). For 1961–1983, Norin Suisan Sho, Nogyo Chosa, (Ministry of Agriculture, Forestry and Fishery, Survey of Agriculture).

FIG. 3. SHIPMENT OF THE WALKING TYPE TRACTOR, DISPOSABLE INCOME OF THE AVERAGE FARM HOUSEHOLD, AND RELATIVE PRICE OF TRACTOR AND WAGE RATE



Sources: Shipment of the walking type tractor and prices of the walking type tractor: same as Figure 1. Disposable income per farm household: Norin Suisan Sho, Noka Keizai Chosa Hokoku (Ministry of Agriculture, Forestry and Fishery, Report of Farm Household Economy Survey). Wage rate of Agricultural Worker: Norin Suisan Sho, Noson Bukka Chingin Tokei (Ministry of Agriculture, Forestry and Fishery, Statistics of Prices and Wages in Rural Areas).

walking type tractors which were an ecologically adapted and economically viable form of agricultural technology. Some additional reasons which led to the increase in tractorization in Japan include:

① The purchasing power of farm households increased as a result of increases in income. Many owner-farmers were created by the Land Reform after World War II and were, hence, more motivated to improve their farm management practices. Rice yields stabilized at a high level after 1950, for example, because of a number of improvements in rice cultivation technology. The price received by farmers for their rice also increased after 1951 and led to a considerable increase in rice growers' income. During this period of high economic growth most farm household members worked off the farm or on the farm on a part-time basis only. Farm household income was raised mainly by this increase in off-farm employment. Farmers' demand for tractors paralleled the rise in farm household income.

② As noted above, a large portion of the agricultural labor force was withdrawn from farm households during the period of high economic growth. This result in a drastic decrease in the agricultural labor force, especially in the number of young laborers, and led to an increase in the agricultural wage rate. Under these conditions, farmers began to view tractors as an important and suddenly more affordable labor-saving technology.

③ The marginal disutility of farmers' own labor increased as a result of increases in their income and the modernization of farmers' lifestyles. This prompted farmers to try to reduce the amount of time they spent doing hard manual labor (e.g., land cultivation) by adopting tractors.

④ Finally, public investment in land improvement projects increased considerably after World War II. These projects made it easier to use walking type tractors for agricultural purposes and thus also expanded the use of tractors in Japan.

The Role of the Public Sector in the Development of the Walking Type Tractor

(1) The Pre-War Period. It is noteworthy that farm machinery and implements producers worked closely with farmers in villages to invent and produce the power tiller. Public sector institutions such as the Ministry of Agriculture and agricultural experiment stations, in contrast, played primarily an indirect role in the development and diffusion of the power tiller. This role is described below.

First, as previously noted, an agricultural experiment station carried out a comparative examination of imported garden tractors in 1922. Although the results of the study suggested that imported garden tractors were not well suited to Japanese agriculture, the study made clear the importance of developing a cultivating machine which was adapted to local agricultural conditions. Secondly, the Ministry of Agriculture and Forestry promoted the diffusion of the power tiller by holding national machinery and implements fairs. At a national farm machinery and implements fair held in Okayama City in 1929, for example, four kinds of power tillers were introduced to the public. A national demonstration of the power tiller was held under the auspices of Okayama Prefectural Nokai with the support of the Ministry of Agriculture and Forestry and the Okayama Prefectural Agricultural Experiment Station in 1941. This demonstration helped to promote the diffusion of the power tiller.

A third way in which the public sector assisted in the development and diffusion of agricultural technology was by conducting trials of power tillers. This also provided farmers a guide for purchasing power tillers. At the comparative examination held at Okayama Prefectural Agricultural Experiment Station in 1938, for example, four kind of crank type power tillers and 14 kinds of rotary type power tillers were exhibited. The results of this test were published in a document titled "Result of Comparative Examination of Small-Scale Power Tillers." A similar comparative examination of the power tiller was held at Gifu Prefectural Agricultural Experiment Station in 1939.

Finally, the Japanese government aided in the development and diffusion of tractor technology by promoting the domestic production of a small-scale petroleum engine. Since a prime mover of the power-tiller was the petroleum engine, the development of a small-

scale, light, efficient and low-cost petroleum engine was crucial. The Ministry of Agriculture and Commerce let Dainihon Nokai offer a prize for the invention of a small-scale petroleum engine, for example, in order to stimulate the production of such engines for agricultural use. The Ministry of Agriculture and Commerce also carried out comparative examinations of small-scale petroleum engines in 1922, 1925 and 1930 in order to stimulate the research and development of agricultural petroleum engine producers as well as to provide farmers with guidelines for purchasing petroleum engines.[10] The agricultural petroleum engine industry was established around 1930. The price of petroleum engines began to drop when they started to be mass produced. Improvements in the petroleum engines to increase fuel consumption efficiency and decrease weight per horsepower also helped aid the development and diffusion of the power tiller.

(2) The Post-War Period. The role of the public sector in the development and diffusion of tractor technology after World War II is as follows. First, the Minsitry of Agriculture and Forestry issued a Regulation on commissioned testing of farm machinery

TABLE 6. RESULT OF NATIONAL TESTING OF THE WALKING TYPE TRACTOR

Year	Type of the tractor	Number of units passed testing
1955	D	32
	C	14
1956	D	11
1957	P	38
1958	D	23
	C	21
1959	D	11
	P	12
	C	4
1960	P	11
	C	8
1961	D	18
	P	13
	C	15
1962	D	10
	P	9
	C	4
1963	D	6
	P	6
	C	12
1964	D	2
	P	3
1965	P	8
	C	7
1966	D	12
	P	5
	C	3

Note: D stands for Driving type, P stands for Pulling type and C stands for Combined type.
Source: Shinnorinsha, One Hundred Years of Farm Mahcinery Industry, 1968, p. 206.

[10] Aizawa, Toshio "Nokigu Gyosei no Enkaku III (History of the Administration of Farm Machinery and Implements III)," Nokigu (Farm Machinery and Implements), January, 1943.

in 1949. It initiated such testing in order to eliminate poor-quality products and otherwise improve the manufacture of farm machinery.[11] With respect to the walking type tractor, national testing was first performed at Niigata Prefectural Agricultural Experiment Station in 1952 when 30 walking type tractor units from 30 different companies underwent testing. With the enactment of the Farm Mechanization Promotion Law in 1953, the farm machinery testing scheme was legalized. This testing was conducted upon request, however, and was not compulsory. Any machinery which passed testing had a certificate attached to it which proved to be a valuable guide to farmers in the market for a tractor. Results of the national inspections of walking type tractors are shown in Table 6.

Secondly, the Ministry of Agriculture and Forestry entrusted the Okayama Prefectural Experiment Station to conduct research on small-scale power tillers from 1947–48. In this way, the transmission clutch was improved and engines were made smaller and lighter. A third strategy of the public sector involved the enactment of the Farm Mechanization Promotion Law whereby the Japanese government imported foreign machinery for examination and provided loans for mechanization purposes. The Institute of Agricultural Machinery, for example, was established as a result of an amendment to the Farm Mechanization Promotion Law in 1962. The purpose of this Institute was aimed at meeting the growing need to accelerate farm mechanization, expand research activities and strengthen the farm machinery testing scheme.[12] The Institute has played an important role in strengthening basic research for the development and improvement of farm machinery as well as in the testing and evaluation of farm machinery.

III. *Conclusion*

The development of the walking type tractor in Japan can be considered as a case in which an appropriate technology was created through adaptive research and development with reference to advanced technology in foreign countries. The Japanese power tiller, as we have seen, was developed around 1930 or about ten years after the import of garden tractors. Small-scale producers of farm machinery and implements developed the early power tillers in cooperation with farmers who were the designated users of such technology. The power tiller, however, was incomplete in structure and broke down frequently. As a result it was used only in certain areas such as Okayama, Fukuoka and Niigata Prefectures.

By the middle of the 1950s several kinds of walking type tractors had been developed by borrowing designs from abroad and correcting the defects in the power tiller. Medium and large-scale enterprises possessing a high level of technological sophistication began producing small-scale tractors which were well-suited to the ecological and socio-economic conditions of Japanese agriculture after a period of adaptive research and development.

The success of the walking type tractor can be attributed, in part, to four factors. First, the tractors were developed so that they were consistent with the factor endowments present in rural areas at the time. The price of the power tiller before World War II was cheap relative to the price of imported garden tractors, reflecting the scarcity of capital and

[11] Asian Productivity Organization, Farm Mechanization in Asia, 1983, p. 205.
[12] Asian productivity Organization, ibid., p. 206.

the low purchasing power of farmers. The price, for example, was about two to three times that of a draft animal but only one-quarter or one-fifth that of a Simar tractor. After the war as the agricultural wage rate increased and farm income rose, more sophisticated tractors with greater capacity were developed. The substitution of draft animals and manual laborers with the walking type tractor proceeded at a fast pace.

The second factor responsible for the successful development of the walking type tractor involved the development of the farm machinery and implements industry itself. The power tiller's structure, it will be recalled, was quite simple reflecting the low level of technological sophistication present among small-scale farm machinery and implements producers before World War II. It was designed ,in fact, by simplifying the structure of the more complicated imported tractors. After World War II, however, as the farm machinery and implements industry in Japan became larger and more modern, the structure of the tractor became more complicated and its quality and capacity improved considerably.

A third factor had to do with the social organization of agriculture in Japan. As noted earlier, the average size of farms in Japan were very small (e.g., about 1.0 ha) and, in addition, plots of land were often scattered. The walking type tractor was developed in accordance with these features of Japanese agriculture. It was, for example, small-scale, light, and capable of being used for a variety of purposes. Finally, whereas the imported garden tractors could only be used to cultivate upland fields, the Japanese walking type tractor was designed and improved upon so that it could operate effectively in wet paddy fields. The history of the evolution of the walking type tractor thus reflects a continuous process of tailoring imported tractor technology to the changing conditions and needs of Japanese agriculture.

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